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PERFORMANCE ASSESSMENT DEVELOPMENT FOR A LILW REPOSITORY IN SLOVENIA

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ABSTRACT

Simultaneously with the site selection process for a low and intermediate level radioactive waste (LILW) repository, the preliminary assessment of the influence of the specific disposal concept on the environment and on the population was developed. The performance assessment team, organized in 1997 by ARAO, prepared several basic studies in order to clarify the objectives of the performance and safety assessment (PA/SA) procedure. In 1999 also the first performance assessment of two safety cases (surface and underground) for generic site for a LILW repository was realized.

In the year 2000 activities on PA/SA analyses continued. A systematic, generic list was prepared of all possible features, events and processes (FEP list) predictable for surface or underground LILW disposal in Slovenia. Recommended and selected were the most reliable scenarios with conceptual models for LILW disposal in normal and altered evolution conditions. New verification of the obtained results was done with more powerful and accurate models for the surface repository over an aquifer of lower water permeability and an underground repository in a plastic rock. The results for both generic cases under normal evolution scenarios showed that there is a negligible dose influence on members of the critical population due to the migration of radionuclides from the foreseen LILW repository. The results of the already performed work as well as plans for the future activities are presented in the paper.

1 INTRODUCTION

The natural predisposition of the host rock and its surroundings together with the repository system, which consists of radioactive waste, placed in concrete modules and filled with a suitable filling, have to be assessed in order to evaluate possible influences from the specific repository concept on the environment and on the population. For a safety assessment first a performance assessment for the repository has to be made, in which the behaviour of the repository together with engineered barriers and its surroundings is thoroughly analysed. Performance assessment is especially needed in the site selection procedure where decisions related to design, engineered barriers and host rock have to be optimised. To demonstrate the long term safety of a disposal a model of operation of the repository, geosphere and biosphere is prepared over a longer period. In this model all the possible features, events and processes inside the repository and between the repository and its surroundings have to be accounted for.

The Agency for Radioactive Waste Management, ARAO, re-initiated the site selection process for the LILW repository in 1996. Parallel with the new siting the disposal concept is also being developed. In order to evaluate the acceptability of the proposed disposal concept the preliminary assessment is being started as well. In the process of preparation of such an assessment we have taken into consideration the fact that the site for the repository is not yet known and the decision on whether to build a surface or underground repository has not yet been made. Due to the small amount of long-lived LILW compared to short-lived LILW (approximately 98 %), we assumed that the repository would be intended only for the short-lived LIL waste.

The performance assessment team[1], organized in 1997 by ARAO, prepared several basic studies based on experiences gained by participating in the international project ISAM (Improvement on safety assessment methodology for near surface LILW repository) led by IAEA since 1997 [1]. We have directed our efforts towards framing the objectives of the performance and safety assessment (PA/SA) procedure: the assessment context, the input parameters for the assessment and the timeframes for the assessment. These studies were followed by research on radionuclide influence on the different materials which compose waste-form, and on migration processes through engineered barriers and geological surroundings, together with their time dependence [2], [3].

In 1999 the first preliminary performance assessment of two safety cases (surface and underground) for generic site location for a LILW repository was performed [4]. All required data and descriptions of generic location, waste, disposal system and assessment context, were prepared for two disposal concepts/siting options. Scenarios, based on the screening of all possible features, events and processes (FEPs) for Slovenian conditions, were generated for normal future evolution and for less probable but anticipated conditions which might occur in the repository and its surroundings in the next couple of hundred years. Calculations, based on the AMBER computer code [5], were applied at that stage. The results were optimistic and showed that the influence of the proposed disposal concept is in compliance with the criteria which are internationally recommended.

In the year 2000 activities continued with preparation of a special programme for PA/SA implementation in which recommendations from previous studies, results from initial calculations and development in ISAM project were taken into consideration. We started with a new, more accurate and comprehensive PA stage for two safety cases [6], for the still unknown location, but with the limitation of including two most probable combinations of geological environment/type of disposal facility:

- for surface repository above an aquifer,
- for underground repository in a plastic rock with low permeability,

2 MODEL

The work on the performance assessment for the surface and underground safety case followed the methodology proposed by the ISAM programme, which is shown in Figure 1. All key elements of the PA/SA model (assessment context, disposal system with radioactive waste identification, scenarios generation, conceptual and mathematical models identification) were defined having in mind the purpose of the assessment which has been limited to the site/disposal concept selection phase, and restrictions resulting from that stage. The characteristics for the individual disposal system were taken from the already prepared basic conceptual designs for both a surface and an underground repository.

[1] For this purpose an expert team from different Slovenian organisations was formed (ARAO, National Slovenian Civil Engineering Institute, Geological Survey of Slovenia, University of Ljubljana – Faculty of Mechanical Engineering).

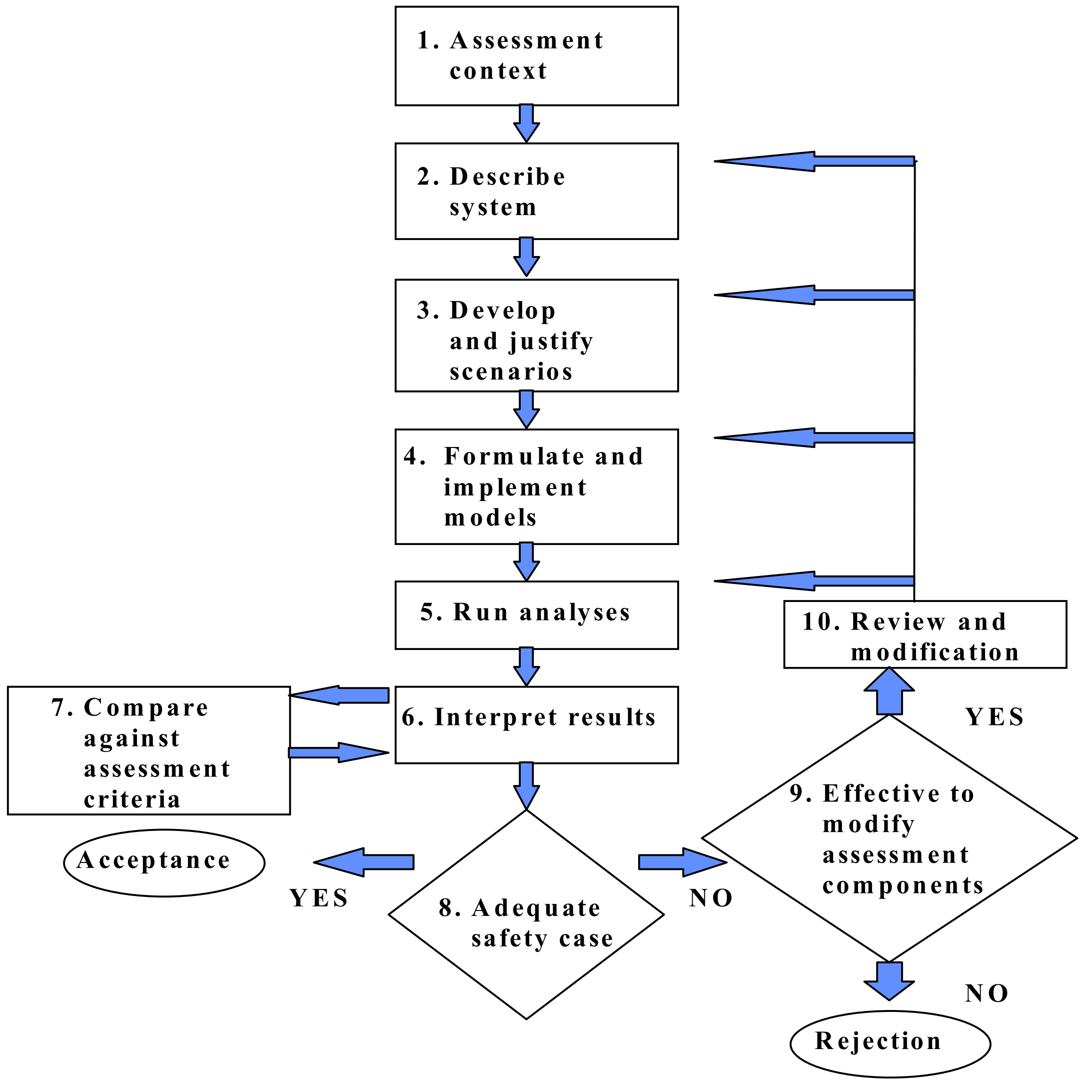

Figure 1: The PA/SA approach (according to the ISAM recommendations)

2.1 Assessment context

***The purpose of the assessment*:**

- To evaluate potentially suitable locations as part of a siting/disposal options procedure and to compare the two different sites/options in terms of the level of compliance with regulatory requirements.
- To contribute to confidence in the negotiations between the local community, the regulator and the investor.
- To identify key areas of uncertainty that could be investigated in the next stage of the site characterization programme.

***Regulatory framework and timeframes*[2]:**

- The annual individual effective dose to a member of the critical group from the disposal facility is limited to 0.3 mSv/year.
- Closing period of the disposal: 5 years.
- Institutional control: 100 years of active control of the site after the end of disposal operations, further 200 years of passive institutional control after the end of active control.

[2] Due to the lack of Slovenian requirements ISAM recommendations were used.

- No predetermined time cut-off beyond which impacts need to be considered.

Other assumptions in accordance with the international praxis:

- Constant environmental and societal conditions are considered for this early assessment stage.
- Generic central European biosphere conditions are assumed with a stable, continental climate.
- The design, construction and monitoring of the disposal facility are assumed to perform without major defects.

2.2 System description

Disposal system characteristics:

- The surface repository is a vault type facility, consisting of 10 disposal units–vaults, located above an aquifer in the host rock or soil with very low permeability.
- The underground repository is a facility with horizontal access (tunnel type of repository) in plastic clay rock, which is spread over a large part of the Slovene territory.
- A multi-barrier system is foreseen for both types of repositories: concrete, drums, backfill, concrete blocks, vaults, drainage system, cap (in the case of surface facility) or surrounding host rock with low permeability (in the case of tunnel type repository).
- The overall repository dimensions including waste acceptance, treatment, conditioning and disposal facilities are assumed to be 300 x 200 m.
- Both sites are assumed to have a relatively simple geological structure with limited tectonic activity.

LILW waste inventory:

The waste to be assessed is primarily short-lived L/ILW from the operation of the Nuclear Power Plant Krško and its decommissioning. Also some long-lived isotopes can not be excluded from the calculations, since they represent the major contribution to the groundwater contamination in the longer period due their solubility and ability for migration. According to the estimation the total waste quantity is expected to be approximately 18,000 m^3. It consists of the radioisotopes given in Table 1, which may arise during NPP operation, as activation products or during decommissioning[3].

Table 1: Inventory description for PA/SA analyses

Radionuclide	$T_{1/2}$ [a]	Initial activity [Bq]
H-3	1,23E+01	1,75E+11
Co-60	5,27E+00	5,99E+13
Sr-90	2,91E+01	4,64E+10
Cs-137	3,00E+01	7,71E+13
Ni-59	7,50E+04	1,80E+13
Nb-94	2,03E+04	7,20E+10
I-129	1,57E+07	1,23E+08
U-238	4,47E+09	1,02E+08
Pu-241	1,44E+01	8,17E+08

[3] For the purpose of PA/SA the waste inventory was assessed from NPP operational data (Co, Cs, Sr, I, H from Krsko NPP), from foreign data on decommissioning waste (Ni, Nb – activated products), and minor actinides contribution due to fuel leakage (U, Pu and their daughter products also from foreign examples).

2.3 Scenario development and justification

A systematic, generic list of all-possible features, events and processes (FEP list) predictable for surface or underground LILW disposal in Slovenia was prepared. All possible FEPs which could significantly influence the performance of the proposed disposal system and the release of radionuclides, and which are relevant for present and future conditions, including anticipated and less probable events, were considered. After the screening of the FEP list by applying the assessment context (scope of scenario generation, level of evaluation, calculation endpoints, timeframes) and the most important parameters describing the disposal system (design, waste identification, geology…), the scenarios with descriptions of normal and alternative, but internally consistent future evolutions and conditions were generated for the surface (vault) and underground (tunnel) disposal facility, and are presented in Table 2.

Table 2: Scenarios for surface and tunnel type of LILW repository for generic location

Surface type repository above an aquifer	[1] **Underground type repository in plastic rock with low permeability**
Normal evolution scenario-NES	*Normal evolution scenario-NES*
1. Cap present but slowly degraded after 100 years, slow corrosion in the near-field; leaching of radionuclides into the aquifer. 2. Cap fails completely after 300 years, leaching of radionuclides into the aquifer.	1. Excavation damaged zone not far from the disposal units. Construction method enabled low disturbance of surrounding rock. 2. Excavation damaged zone spread up to the surface.
Alternative evolution scenarios-AES	*Alternative evolution scenarios-AES*
• Cap and bunker fails, water level rises due to climatic changes or human intervention, “bathtubbing”	• Earthquake causes preference water paths through the rock, followed by leaching.
• Direct human intrusion by digging or drilling	• Human intrusion
• Gas release through the damaged cap	

2.4 Conceptual model formulation and implementation

Consequences of different behaviour of the disposal concept were analysed by describing scenarios through the conceptual models, i.e. detailed simulations of the processes taking place inside the particular parts of the repository system. Modelling of the whole disposal system was divided into three subsystems:

1. near field of the repository itself and its close surroundings where radioactive isotopes migrate through engineered barriers by advection and diffusion transport,
2. far field or geosphere, which accounts for the processes taking place from close surroundings of the repository to the juncture with the biosphere where the hydraulic conditions of the groundwater define migration of the radioisotopes, and
3. biosphere where all interactions from groundwater to human (water pumping, crops irrigation, animal and fish consumption) should be taken into consideration.

Verifications of the obtained results were done with powerful and accurate computer codes. The modelling took place in three successive steps following the conceptual models:

- *the near field modelling*, run by PORFLOW [7] computer code, giving the flow paths and transport of radionuclides leaving the near field,
- *the geosphere modelling*, first with the hydraulic field and then with transport calculations for the whole mass flow entering the geosphere through the near field (GMS computer code [8])
- *the biosphere modelling,* taking as a starting point the radionuclide concentrations in groundwater and in the stream and calculating the final dose to a member of the critical group. The calculations were run by AMBER code [5].

3 RESULTS

Before discussing the results for the two disposal systems, it is important to be aware of the following caveats:

- For the purpose of the study in the year 2000 only the normal evolution scenarios were used. The alternative evolution scenarios will be implemented within the next modelling step.
- The results are initial and illustrative, PA studies at this step were meant primarily as a part of the learning process.
- The sensitivity and uncertainty analysis which has been undertaken is very limited - for parts of subsystems only.
- The applied geometry was simple, consisting of three different materials. The radioactive inventory has been considered to be regularly distributed in the waste zone.
- For the calculations, as many parameters as possible which are typical for Slovenia were used. Some of the material properties are not yet available (transport parameters, retardation factor, ..) therefore expert judgment based on literature search was used.

The **near field** calculations for the surface repository show that the model is very sensitive to the choice of scenario. In both cases - surface and underground - the transport is advection dominated. The diffusion calculations gave much smaller values for the flux contribution (no radionuclide is exceeding the flux of 1.3E+03 Bq/year). The most problematic contaminant is I-129 due to its longevity and retardation factor equal to 1. In the worst scenario case where the cap fails completely after 300 years, high concentrations of Nb-94 can be found in the near field as well. After the modelling of the underground safety case it was revealed that at the steady state of flux, both fluxes - from the surface and from the underground repository- are the same: 10^6 Bq /year. But that the time required to achieve this in the underground repository is ten times longer as a result of its greater confinement.

The **geosphere** modelling shows that maximum concentration of 30 Bq/m^3 appears in the river only 2600 years after entering the geosphere in the underground repository, whilst the concentrations higher than 1 Bq/m^3 are present in the river between the simulation years of 1600 and 6600. For the surface repository, the calculations show that the radionuclide plume spreads into the stream through the surrounding of the repository between 200 and 400 years after the overcoming the near field barriers. Through the rock the migration is slower. It appears in the river between the simulation years 800 (upper layer) and 2600 (lower layer in the rock). The calculated values for normal evolution scenarios for both safety cases are extremely low, lower than the natural radioactivity in soil or in rock.

The results of the **biosphere** calculations for surface and underground repository show that all doses are bellow the dose constraint of 0.3 mSv/year although during calculations several assumptions on input data were taken. The GMS model assumed a constant flux of all contaminants from the near-field model of 10^6 Bq/y for 100 years. The AMBER calculations were performed with this total flux assigned to each contaminant. This is clearly a very unrealistic case, which would correspond to much higher activities in the repository than would actually be present. But it does give us the maximum possible annual doses. From table 3, where maximum annual doses from each contaminant for two types of repository are listed in the layer where maximum is achieved, it can be seen that the maximum annual dose is 1.5 times smaller than the maximum allowable annual dose. The differences in dose contributions between the surface and the underground repository are due to the different conceptual models, which influence the contaminant transport to the human and will have to be investigated in the future.

Table 3: Maximum annual dose from each contaminant for surface and underground repository, NES, layer with the maximum

Radionuclide	Underground [Sv/y]	Surface [Sv/y]
H_3	5.3E-09	2.3E-10
Ni_59	2.1E-08	9.1E-10
Co_60	6.2E-07	2.7E-08
Sr_90	1.2E-05	5.2E-07
Nb_94	5.0E-07	2.2E-08
I_129	3.2E-05	1.4E-06
Cs_137	3.9E-06	1.7E-07
Pb_210	**1.7E-04**	**7.2E-06**
Po_210	**2.2E-04**	**9.5E-06**
Ra_226	**1.2E-04**	**5.5E-06**
Th_229	1.1E-04	5.0E-06
Th_230	3.9E-05	1.7E-06
Pa_233	1.6E-07	7.0E-09
U_233	9.2E-06	4.0E-07
U_234	8.8E-06	3.9E-07
U_238	8.7E-06	3.8E-07
Np_237	1.8E-05	8.1E-07
Pu_241	7.2E-07	3.2E-08
Am_241	3.3E-05	1.5E-06
Rn_222	1.0E-30	1.0E-30

4 THE WAY FORWARD

The performance assessment for the two disposal concepts was prepared on the basis of already prepared studies for the Slovenian LILW repository, foreign practice and international recommendations. The results for both generic cases for the normal evolution scenarios showed that there is a negligible dose influence on a member of the critical population due to the migration of radionuclides from the foreseen LILW repository.

Future work will focus on two main activities. First, more detailed studies will be made on performance assessment of the disposal concept, taking into consideration waste packaging and other engineered barriers in saturated and unsaturated conditions, and flow of radionuclides to the human environment as well as behaviour of the repository concept under alternative evolution scenarios. Improvements in calculations still have to be made, especially with respect to far-field calculations and boundary conditions between near field, far field and biosphere. Due to the present situation when the location of the future repository is unknown, the systematic sensitivity analyses with variations of each parameter should be performed to obtain the evaluation of importance of different factors and parameters.

Secondly, although the performance assessment is preliminary and gives mainly illustrative results, the methods for giving confidence to all interested parties have been explored. It is important that all procedures, methods, partial and final results are carefully and systematically documented providing the traceabillity and possibility of independent verification by repeating the whole procedure.

Additional consideration has to be given also to operational safety, thus providing the basis for an overall safety assessment report which will include routine, accidental and long-term assessment of the disposal concept.

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